ON the SMALLER POLYGONAL CELLS of the GREY MATTER of the SPINAL CORD.

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While engaged in assisting Dr Alexander Bruce in the enumeration of the cells of the Intermedio-lateral Tract of the Spinal Cord, I was struck by a statement of Argutinski's[1] that in the middle cell columns there was a regular and sharply defined segmentation. Although not at that time studying particularly the middle cells, I had observed them fairly closely as they came into near relationship with the intermedio-lateral tract, and this segmentation had not been seen. At Dr Bruce's suggestion, therefore I took up the study of the middle cells of the spinal cord, particularly with regard to their arrangement and distribution in the various segments, at the same time noting the character of the intermedio-lateral tract, but leaving aside the cells of Clarke's column and the motor cells of the anterior cornua except in so far as they come into relationship with the cells under consideration and had to be

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(1) ("On a regular segmentation in the Grey Matter of the Spinal Cord in the New-born and on the Middle Cells", (Arch. f. mikros. Anat., xlviii, 1897, p. 496)

discriminated from them. With the exception of Argutinski, no one, so far as I am aware, has made any special study of the distribution and arrangement of the middle cells. Waldeyer[2] first described these cells and recognised them as a separate and distinct group, naming them the "Mittelzellen." He cites in his paper(p. 124) several authors (Goll, Lockhart Clarke, Beisso, Beaunis et Bouchard, Obersteiner, and Krause) who had mentioned them incidentally, but without giving any details of their distribution or specially naming them. From Waldeyer's own description of them (p. 94, and also under the separate levels of the cord described in detail) the following notes are taken. "The middle cells are found at the junction of the anterior and posterior cornua, but expecially in the former. They are small and medium sized polygonal cells which stain faintly, and they are arranged sometimes in a fairly compact group, or sometimes are more loosely scattered over a wider area. They are never so closely aggregated as are the cells of Clarke's column or those of the intermedio-lateral tract (Seitenhornzellen),

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(2) Das Gorilla-Rückenmark : Abhand. der könig. Akad. der Wissenschaft zu Berlin, 1888.

but they are close enough to be regarded, especially in the upper cervical region, as a special nucleus of cells. Their situation varies somewhat in the different regions of the cord. As a group they are most distinct in the upper cervical region. They lie here closely compacted to the outer side of, or a little in front of, Clarke's column (Figs. 1a, 2b) In the lower cervical region (Figs 2a, 3a) they form a less distinct group near Clarke's column, but quite internal to the postero-lateral motor group. In the upper dorsal region they are also abundant (Figs. 4a, 6a). They are situated laterally and even somewhat posteriorly to Clarke's column, extending into the posterior horn and into the scattered cells of the anterior column without a distinct limit. They are always quite distinctly internal to the margin of the grey matter. With the growth of Clarke's column in the dorsal cord the middle cells become fewer. In the lower dorsal region (Figs. 7a, 7b, 8a), they again become more numerous, no longer form a distinct group but are more in their former position on the outer or antero-external aspect of Clarke's column in great numbers. Similarly in the lumbar cord, though less abundantly developed (Figs, 9a, 9b, 10a). In the sacral cord (Fig. 11a), there is a group of cells which from their character and

situation are probably middle cells, but at this level no characteristic distribution of the various cell-groups is recognisable." Waldeyer was unable to connect these middle cells with any special nerve fibres. Many of the posterior root fibres, he says, approach them, but there is no special connection between them.

Waldeyer's description of some of the other small cells of the spinal cord may also be referred to here. His account of the intermedio-lateral tract is sufficiently referred to in Bruce's paper on that tract.(3) The cells which he calls scattered cells (Zerstreuten-zellen) form no definite group. They are situated (1) in the anterior horns; (2) in the neighbourhood of the central canal; (3) in the Rolandic substance of the posterior horn; (4) in the white matter. With the exception of the latter which often attain a considerable size, they are small or medium sized cells and always multipolar. In the Rolandic substance they occur only singly. The others may be numerous." Those in the anterior horn and in the neighbourhood of the central canal I have not been able definitely to separate from the middle cells, and have included them in my descriptions of that group. But for clearness

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(3) (Trans. Roy. Soc. Edin., Vol.xlv, Part 1, No. 5).

the small cells in the anterior horn are sometimes referred to as the "scattered cells"; those in the neighbourhood of the central canal as the Para-central group - using a term introduced by Onuf and Collins[4] while the cells in the white matter - chiefly in the neighbourhood of the lateral horn - are referred to as Outlying cells, or Outliers.[5]

The Posterior Horn Cells "lie posterior to the level of the hindmost part of Clarke's column. They do not form any well-marked group and are not always present. Four classes of them may be distinguished : (1) Basal; (2) Central; (3) Inner Marginal; (4) Outer Marginal. They are seldom or never all present together and are never in large groups, often only single cells or at most 2-3 cells. In shape they vary greatly, but a long, narrow spindle-shape is the most frequent. In size they vary from small to quite large cells, those on the median margin being largest. Most, if not all, are multipolar, though some may be bipolar. The Basal cells lie immediately behind Clarke's column, Middle cells and Lateral horn cells; the Central cells in the Posterior horn nucleus; the Marginal cell on the inner and outer borders respectively of the posterior horn, the inner or median being

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(4) (Sympathetic Nervous System 1900.)

(5) (Sherrington: Outlying Cells in the Mammalian Spinal Cord, Phil. Trans. Roy. Soc. Lond., 1890).

apparently the more abundant." Waldeyer did not succeed in connecting these cells with any nerve bundles. I have been puzzled how to describe them in the foetal cord. They are not numerous, and not always present; sometimes they can be classified according to Waldeyer's subdivisions, but very often I found it impossible to separate and distinguish them from the reticular group of the Intermedio-lateral tract on the one hand, and from the Middle cells on the other. In appearance and size they are all much alike, and as regards position, the outer marginal might be simply a continuation backward of the reticular group, while the basal and sometimes even the more central and inner marginal ~~were~~ are often directly continuous as a group with the middle cells. Certain cells which I speak of as "Large Posterior Cells" have been particularly noticed. They may be present in the region of any one of Waldeyer's posterior cells but are remarkable for their large size, being very like the anterior motor cells in both size and shape.* Onuf and Collins (l.c. p. 140) define the paracentral group "as situated ventrad of Clarke's column, on each side of the central canal. The longitudinal sections (in the cat) show the group to be segmentally arranged in cell nests. The cells are much smaller than the average anterior horn cells but show some analogy in their chromatic structure. They

are mostly spindle shaped. In man this group seems to have lost its individuality and to form part of Clarke's column except in certain levels (upper dorsal and middle sacral) where a cell group is seen which apparently corresponds to the paracentral group although situated considerably more lateral than in the cat." I have not been able to separate this group from the middle cells and use the term simply as a topographical one. On p. 142 they speak of the cells of the intermediate zone (evidently the middle cells) as "for the most part small, approaching in shape and structure the cells of the lateral horn and of the paracental group. Many are exquisitely multipolar; aside from the small cells a limited number of large ones are seen. Some of them make the impression of being cells of Clarke's column which have strayed away into the intermediate field. Such cells are encountered chiefly in the dorsal part of the zone described. Others are typically multipolar. The large cells are for the most part scattered irregularly, but in some sections they are collected into a group."

Argutinski's observations must now be referred to. His description of the middle cells of the newborn is fuller than that of Waldeyer but differs from his in several points. In particular he finds a regular and sharply defined segmentation of the

middle cell column but limits the system to the dorsal portion of the cord. After a careful and thorough examination of the spinal cord both in longitudinal sections and in transverse sections - including serial sections of a complete spinal cord - I am convinced that this segmentation of the middle cell group does not exist, and further that what Argutinski has described is the segmentation of the reticular group of the intermediolateral tract.

To explain this difference of opinion I must give some of Argutinski's paper at greater length :(p. 505) "If we take a longitudinal section in front of the central canal, or of the central part of Clarke's column, we see in the lateral parts of the grey matter, somewhat inwards from the lateral columns groups of small cells of somewhat similar size in a row parallel to the long axis of the cord - groups which go through the whole length of our sections, without any connection between each other and separated by approximately similar intervals . . . . They lie in the outer third of the grey matter, sometimes nearer the lateral, sometimes nearer the median border of this third. Although always near the margin of the grey matter yet the cell groups never lie directly against the lateral columns." (p. 506) "If we compare the vertical

intervals between the cell groups with the depth of the groups themselves we find that the distance between the neighbouring groups is markedly greater than the longitudinal diameter of the groups themselves." (p.507) "These cell groups are to be found uniformly throughout the whole dorsal region but they are confined to it. With the appearance of the motor cell columns characteristic of the lumbar enlargement our cell groups completely disappear . . . . At the commencement of the cervical enlargement in the region of D 1, after the appearance of the motor cell columns characteristic of this enlargement, the cell groups do not immediately cease, but they extend a little beyond the margin of the dorsal cord." (pp. 508, 509, 510) "From the longitudinal sections we might suspect that they had to do with the so-called lateral horn cells. Although indeed according to their position in transverse sections, they must lie not very far from the lateral horn cells, yet the results of longitudinal section shew that they can be no lateral horn cells. Firstly because our cell groups do not extend quite to the lateral column whilst the lateral horn cells are on the extreme margin of the grey matter and even extend into the white matter, and secondly because in our preparations the real lateral horn cells are to be found only at frontal levels in front of the central canal,

while our cell group is to be found more dorsally, about the level of the posterior commissure or even still further dorsally. Conclusions as to their position and systematic arrangement are only possible from transverse sections. In many transverse sections we find on both sides of the grey matter, towards the back and medium parts of the lateral horn cells, a pretty sharply defined group of not very numerous cells, characterised both by its position and by the direction of its cells. We note at once that this cell group is absent in many transverse sections on one side or the other. Also here and there the lateral horn cells are absent on one side - very rarely on both sides at once - but the absence of our group is much more frequent. Our cell group, found in the middle region of the grey matter between the anterior and posterior horns, belongs to the category named by Waldeyer "Mittelzellen", and will be referred to as middle cells and middle cell-groups. To the same middle region of the grey matter belong the lateral horn cells which probably cannot be distinguished functionally from the middle cells. The middle cells are found always in the neighbourhood of the lateral horn cells, sometimes close to, sometimes further from them. As a rule they lie near the curve inwards of the middle region of the grey matter at its junction

with the posterior horn; in other cases they lie nearer to the lateral horn, and to its cells, sometimes quite close to them or even in direct contact with them, so that it seems as if the middle cells had become joined with the lateral horn cells. In some cases the middle cells are no longer to be found in the position cited but lie more or less medially. That the groups lying in that position are none other than our middle cells is shown by this - that all transitions may be found between these two positions, and that except the middle cell groups and the columns of lateral horn cells, we know of no other separate cell groups either on transverse section or on frontal section in the middle region of the grey matter of the dorsal cord, but only of isolated cells. Further we have the circumstance that if the cell group is seen lying closer to the median line the middle cell group is absent from its usual place.

If we might draw a conclusion as to the origin and changes of position of the middle cell group, without having investigated the stages of development of the human cord, we might take it that the middle cell group sometimes wanders from the middle region of the grey matter near the central canal towards the lateral region of the same, and sometimes even takes up its position definitely in the anterior horn cell columns and Clarke's column."

(pp. 512, 513, 514) "To understand the middle cells we should go further into the lateral horn cells. First let us take them in frontal longitudinal sections. Contrary to the middle cells, the columns of which we found without exception in every series of frontal longitudinal sections to be quite regularly segmented, we find in a section which goes through the tip of the lateral horn, that the lateral horn cells are usually in a more or less uninterrupted cell column which not only extends to the margin of the lateral horn, but goes partly into the lateral column of the white matter. Whilst in a frontal section of this kind we usually find little or no interruption in the lateral cell column, we may find in some of the following frontal sections which lie more ventrally, or more often in those lying more dorsally, alternating swellings and diminutions in the parts of the lateral horn cell column in question, or even interruptions, often many in number and at more or less uniform intervals. These results in the lateral horn cell column can in no way be considered as uniform with the sharply defined segmentation of the middle cell column in frontal longitudinal sections. If we consider the lateral horn cells in transverse sections we see that they are distinguished in many respects from the middle cells. First in their direction :

In both this is a horizontal one, but whilst the lateral horn cells are mostly directed laterally, the middle cells, if in their usual site, are directed from in front outwards and backwards so that the directions of the middle cells on the two sides of the spinal cord form an angle open posteriorly. Secondly we note that while the shape of both series of cells is more or less elliptical or spindle-shaped, the lateral horn cells are more flattened and narrower, the middle cells being broader and more protoplasmic . . . . . In sagittal longitudinal sections we see the middle cell groups sharply isolated from each other, as small masses of cells at uniform distances from each other, but found in fewer sections than in the frontal series. But in a consecutive series of sagittal longitudinal sections we meet yet another longitudinal chain of cell groups just in the neighbourhood of the middle cell groups. This is the column of lateral horn cells. It not infrequently lies in one and the same section as the middle cell group, somewhat more laterally and to the front of the latter. On account of this position, one does not as a rule, when the section is exactly sagittal, find both cell columns in one section. Either one sees the lateral horn cell column only or the middle cell group only, the other being absent or represented only in fragments here and there.

If the lateral horn cell column be followed in a series of sagittal longitudinal sections, from the lateral column to the middle line we find as we near the lateral horn first one or two longitudinal rows of single cells, like pearls on a chain, arranged between the longitudinal fibres of the lateral column. Then we come first into the region of the grey matter of the lateral horn, then to its basis and finally into the wide lateral field of the middle region of the grey substance. When we reach the lateral horn cell column we note in a few consecutive sections that this column has without doubt also a segmentation, and indeed a better one than in frontal longitudinal sections. The single cell nests of the lateral horn cell column are indeed larger than those of the middle cell group, but the intervals between the centres of the two groups are uniform both in the lateral horn cells and in the middle cells, so that both columns form chains which possess the same number and the same disposition of cell groups. The varying size of the cell groups which have uniform intervals between their centres makes it clear that the free spaces between the two cell groups must be different in the two columns; naturally it is smaller in the lateral horn cell column; indeed it may be so small that in the lateral horn cell column one group may extend directly to the

next group. If, as we find in certain sections, there is a distinct transition of one group into another, then instead of a row of cell nests, we have a more or less uninterrupted column of cells. This grouped character is more clearly marked in the medial, that of the uninterrupted sequence of cells in the lateral sections of the lateral horn cell column."

It will be seen from these extracts that Argutinski's description of the double chain of segmented cell-columns is based principally on longitudinal sections, but that, as he himself says, conclusions as to their position can only be drawn from transverse sections. That this double chain exists I fully admit, but I hold that it is formed of the two constituent groups of the intermedio-lateral tract and not of the middle cells and lateral horn cells, and further that Argutinski's description of the middle cells as seen in transverse section is in most points an excellent description of the reticular cell group. Waldeyer, as is pointed out in Bruce's paper, included the reticular group in his "Seitenhornzellen." Argutinski does not do so - he only includes the apical group of the intermedio-lateral tract under that heading, and he states categorically that "our cells can be no lateral horn cells." In both points

I think he is in error. If throughout his paper we read for "Seitenhornzellen" apical cells, or apical group, and for "Mittelzellen", reticular cells or reticular group, we get an excellent description of the intermedio-lateral tract. To show that this is so I have enumerated below in a short tabular form the points of agreement between Argutinski's "Middle cells" and the reticular group as described by Bruce and by myself in this paper. I shall also point out where the descriptions differ and endeavour to explain how these differences have arisen.

Points of Agreement :

(1) Longitudinal limitation of the group. Almost exact agreement, though both Bruce and myself find it rather lower than Argutinski does.

(2) Lying in the outer third of the grey matter.

(3) Very near to the lateral horn cells (apical group), sometimes even in direct contact with them.

(4) Lying posteriorly and internally to the lateral horn cells, usually close to the re-entrant reticular angle.

(5) Direction of the cells - inwards and forwards.

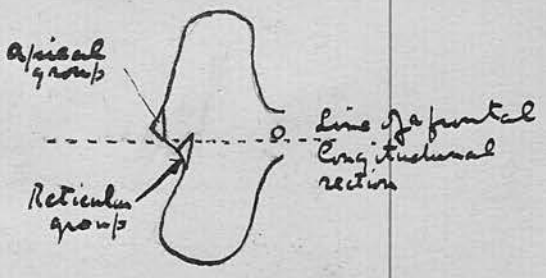
(6) Shape - like the apical cells but broader.

(7) Parallel segmentation of the apical and reticular groups (Seitenhorn- und Mittel-zellen;(Argutinski)

the segmentation a much sharper one in the reticular group (Argutinski's Mittel-zellen).

Points of Non-agreement are as follows :

(1) Argutinski's middle cells never approach quite closely to the lateral columns - a point which he insists on strongly as distinguishing them from the "Seitenhornzellen". Well, in the cord of the new-born the reticular group not infrequently does lie a little way from the edge of the grey matter, sometimes even a considerable distance (see particularly under D 3 and D 12). Moreover from the shape which the reticular cell group so often has it is obvious from the accompanying diagram that many frontal longitudinal sections would show the reticular group quite internal to the edge of the grey matter. But I cannot agree with Argutinski when he says the group never approaches quite to the lateral columns.



(2) Then he describes his cells as sometimes departing from their usual position and being found more or less mesially or even in the region of the anterior horn cells or Clarke's column cells,

and that all transitions may be found between these positions.

It is obvious that here he must be referring to the real middle cells of Waldeyer, and I am in complete agreement with this statement. But when he says further that if the cell group is seen lying closer to the middle line, his middle cell group (reticular group) is absent from its usual place I must part company from him, and can only differ without explaining. Certainly I have often seen a reticular group in its usual situation and a group of middle cells present in another part of the same section.

The material used for the present investigation was as follows. A spinal cord was obtained from a mature full-time child which died almost immediately after birth. The sectio was made about twenty-four hours afterwards. On removing the cord it was placed directly into absolute alcohol and hardened for twenty-four hours before cutting into segments. The division into root segments was made by cutting transversely just below the lowest fibre of each nerve root. Unfortunately at the sectio the upper

three cervical nerve roots were injured and the lower three sacral roots were cut before their passage through the dura mater, so that the boundaries of the upper three cervical segments, and of the lower three sacral segments and of the coccygeal segments can only be taken as approximately accurate. As each segment was cut off, a longitudinal nick was made in the right posterior column so that there could be no confusion of the upper and lower ends of the segment, or of the right or left sides, in the various stages of embedding and cutting, etc. The segments were passed through benzole, embedded in paraffin and cut into thin uniform serial sections on a rocking microtome, and a convenient number (20, more or less) mounted on each slide, the slides being albumenised to lessen the risk of any section being lost. During the progress of the work the tube containing the 5th lumbar segment was broken unawares and the segment became shrivelled and useless. The 5th lumbar segment from a cord of practically identical age and accurately divided from below upwards has therefore been used for the description. The sections were stained with Giemsa's stain (azure blue and eosin) in the following manner :

(1) Pour on sufficient of Giemsa's solution to cover the sections. Leave about three minutes.

(2) Dilute with an equal quantity of distilled water and allow to stand for about seven minutes.

(3) Wash off with distilled water. Remove excess of water from the sections.

(4) Decolourize in absolute alcohol containing from a few drops to 1 c.c. of acetic acid per 100 c.c. of alcohol.

Requires 10 -30 seconds usually. Is sufficient when blue stain ceases to come out and to the naked eye sections appear almost uniformly pink.

It is best to examine the nerve cells under the low power of the microscope to see if the decolourization is sufficient.

(5) Wash with pure absolute alcohol. Pass through benzole and mount in Canada balsam.

This method was adopted as being a convenient and rapid one (in consideration of the number of sections - over 15,500 individual sections, or about 700 slides) and as giving readily a sufficiently sharp picture of the cells of the grey matter for low power work. Had I known at the time of [redacted] the method of staining en bloc with methylene or polychrome blue, I should have used it as being a more rapid process and as

giving a cell stain equally well adapted for low powers and rather better for high powers than the method described above of using Giemsa's stain.

These sections have all been conscientiously examined. D 2 was selected to commence the examination with, as being a segment in which I knew the cell distribution pretty well in the adult cord, and from that level I worked down to the lower end of the cord and then upwards to the upper end. But for convenience the descriptions have been given consecutively from above downwards, commencing with C.1. Rough notes were made of the sections as they were examined and when each segment had been gone over, its characters were summed up while they were fresh in the memory.

At first when the possibility of the middle cells having a segmented arrangement was before me, I attempted to enumerate them with the idea of representing the numbers graphically, but it soon became evident that no such segmented character existed, and that little would be gained by enumeration of the cells as a whole. Possibly some facts of interest would be brought out if the cells in the different areas (see below) of the middle region of the grey matter could be enumerated separately and charted, but I doubt it very much. The boundaries are so indefinite and the

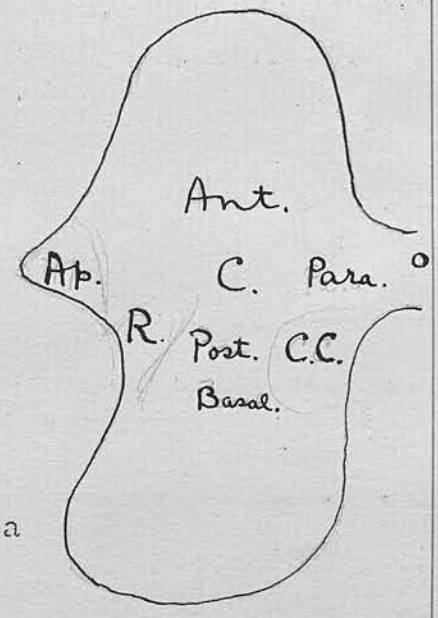
cells are never confined strictly to any one. To enumerate the cells as a whole would be of considerable interest, especially if the other cell columns (motor, Clarke's column and intermedio-lateral tract) were tackled in the same cord, but the time required for such a work would be very great and I could not attempt it in the present instance. To eliminate more thoroughly ~~eliminate~~ the possibility of there being any segmentation in the middle cells, a second endeavour was made to count the cells in a lower dorsal segment (D 10), and the same result was obtained :— the figures gave no sign of any regularity of grouping.

Some difficulty was felt with regard to nomenclature and division of the grey matter into areas. Miss Fitzgerald (7) in an investigation into the sectional area of the grey and white matter of the lumbo-sacral cord recognises only an anterior and posterior horn divided by a line from the central canal to the innermost part of the lateral columns (in the reticular angle). Waldeyer (l.c., footnote, p. 98) recognises three regions in the grey matter : a free anterior horn, a middle region and a free posterior horn. The middle region is defined as including

(7) (Proc. Roy. Soc., Series B., Vol lxxviii, No. B. 523)

the central canal, both transverse commissures, the lateral horn, the region of the middle cells and Clarke's column. Everything in front is the free anterior horn; everything behind the free posterior horn. But it is evident that to describe in detail the position of the middle cells, some other plan must be adopted, and the terms which I have used in the description are best explained by reference to the accompanying diagram.

C.	Central area
Ant.	Anterior or anterior central area in the base of the anterior horn.
Para.	Para-central area
Ap.	Apical or Lateral Horn area
C.C.	Clarke's column area.
Post.	Post-central area
R.	Reticular area or area of the Formatio Reticularis.
Basal	Posterior Basal area.



At most levels these different regions can be recognised, but they are quite arbitrary and only employed for topographical convenience, and it seems quite futile and useless to attempt to define any exact boundaries for them. The middle cells are certainly not in the least restrained by boundaries between these regions. In the cervical and lumbo-sacral enlargements there is of course no apical

region; Clarke's column, though not always represented by cells of that column, still has its "area" there; and an additional external central area might be added.

With regard to the figures given under the heading "Sizes", in the description of the individual segments, they are only of value as indicating the relative sizes of the cells of the various groups. A large number were not measured, the extreme limits are not given, nor are the diameters of the cells in different directions, but the figures may be taken as approximately representing the mean diameter of an average sized cell of each of the different cell columns.

For the photographs which were taken a Zeiss Planar lens of 20 mm. focal length was employed. The sections were selected as showing various typical groupings or occurrences of cells - more being taken in the dorsal region, (where it was thought advisable to represent the intermedio-lateral tract as well as the middle cells) than in the cervical or lumbo-sacral segments. As most were picked so as to have cells present, they may give rather an exaggerated idea of the number of cells, as many sections quite as typical but containing very few cells are not illustrated.

The photographs are numbered thus : D 4, 289 L., for example means the 289th section (from the upper

end) of the 4th dorsal segment, the left side.

In addition to the serial set of transverse sections, longitudinal (frontal and sagittal) sections were made from another foetal cord in the dorsal region, and from various cords, both normal and pathological, sections have been stained according to Cajal's method with the object of trying to trace the nerve fibres of the intermedio-lateral tract and of the middle cells.

I shall now go on to the description of the cells as found in the various segments of the cord.

C 1 : 289 Sections. See Figs. 1-4

Shape :

The posterior horn is rather small and spatulate in shape with a narrow though short neck. The anterior horn is also rather small and narrow from side to side. There is a large loose reticular formation, and on the same frontal level as the central canal a loose-meshed pale-staining area of grey matter projecting outwards as a lateral horn.

Middle Cells :

These vary considerably in number; sometimes there are very few, but, though never very numerous, they are on the whole fairly abundant, especially in the upper part of the segment. They may be scattered diffusely or grouped in various places. In the basal portion of the anterior horn there are practically always middle cells, but they are usually scattered; not often aggregated into definite groups. The commonest group is a central one; it may be a fairly compact nest of cells, up to thirty or so in number; but it is not usually very compact and it tends to extend somewhat into the base of the anterior horn and also into the para-central area; in fact it is oftem as much para-central as central in position. A small group is also of pretty frequent occurrence in the anterior part of the light-staining area - the region

corresponding to the apex of the lateral horn elsewhere. In the reticulum, post-central area and Clarke's column area, the cells are scattered loosely, and in the two latter particularly they are not very numerous. Some outlying cells in the white matter adjacent to the external horn and reticular formation are of pretty common occurrence.

In size the cells vary somewhat, but in any particular part are generally of mixed sizes. Those in the anterior horn, however, are on the whole larger and sometimes there is difficulty in distinguishing them from motor cells. The apical cells also are usually good sized. All are polygonal or rounded polygonal in outline. Their mode of occurrence is typical of the middle cells, i.e., irregular and casual. If a group occurs, it is never present in one site through more than three or four sections at most. When traced further the cells either die out or the group shifts to some other area. Nowhere is there any sign of a segmentation such as is present in the intermediolateral tract of the dorsal region.

Other Cells :

There are several occurrences of single large posterior cells, but they are rare. They may be either in the hinder part of the reticulum or in the centre of the posterior horn. There are also one or two cells that may represent Clarke's column, and twice

a large cell was noted lying on the extreme inner edge of the grey matter opposite Clarke's column area, and once a similar large cell in the centre of the posterior columns. Several single large cells occur in the anterior part of the para-central area; one of them was observed in the anterior grey commissure almost in the mid line.

There are occasional small cells corresponding in position to Waldeyer's posterior basal and posterior marginal cells.

Sizes :

Anterior motor cells	.025 mm.
Clarke's column cells	.020 mm.
Large posterior cells	.018 mm.
Middle cells	.015 mm.

C 2 : 292 Sections. See Figs. 5-8

Shape :

Is much as in C 1. Posterior horn is not quite so elongated. The lateral horn is formed of similar loose-meshed pale-staining tissue, but is rather more distinctly a projecting horn. The reticular formation is also pale-staining and of considerable extent.

Middle Cells :

On the whole they are not very numerous. In the base of the anterior horn there are rather larger ones than elsewhere, and since many of the motor cells are small it is often very difficult to distinguish the two sets. By size and appearance only it may be impossible, but the motor cells are usually in a fairly compact group - either an antero-mediam or an antero-external one - while the middle cells are practically never grouped in this area and are only of casual, irregular occurrence, so that tracing the cells through two or three sections will usually settle the point. A central group of middle cells - about twelve or fifteen in number usually - is a very common feature of the segment; in fact for long stretches it seems to be almost constant. This constancy is rather better marked on the right side than on the left. Sometimes the group is more para-central than central and occasionally it stretches post-centrally.

A small apical group - about six to eight cells - is also fairly common, but there is no regularity or segmental character about its occurrence. It may be at the most projecting part - or apex such as it is - of the lateral horn, but often it is somewhat anterior to this. The cells are usually like the other middle cells in size and shape, but at one or two levels there are some very big cells, like small motor cells; their presence, however, is quite temporary.

In the other regions the middle cells are seldom grouped, usually just scattered thinly. There are not many in the reticular formation, though some apparently even extend into the white matter as outliers; post-centrally and in Clarke's column area there are only a very few small cells.

Other Cells :

There are very few large posterior cells - less than half a dozen, I think in the segment - either posterior marginal (behind reticulum) or central in position.

Only one cell noted that might represent Clarke's column, and one very large cell was observed in the anterior part of the para-central region.

Sizes :

Anterior motor cells	.021 mm.
Large posterior cells	.018 mm.
Middle cells	.014 mm.

C 3 : 407 Sections. See Figs. 9-12

Shape :

Posterior horn pretty small and short and with a very narrow neck. Formatio reticularis still large, but not so loose and pale-staining as C 2. Lateral horn cannot be said to exist as a distinct horn; it is merely a slight projection of the outer border of the grey matter and at the lower end is beginning to be merged into the lateral enlargement of the anterior horn.

Middle Cells :

Are not particularly abundant and are characteristically scattered, sometimes fairly thickly, but more often thinly. In the various areas aggregations or groups may be present, but they are seldom very compact or very large. The commonest is a central one or central-para-central. In Clarke's column area and post-central area, small groups occasionally occur, but they are rare. In the reticular formation, groups are also rare, but there are frequently a few cells present and sometimes they even appear to be beyond its strands, free in the white matter. An apical group is also uncommon, though there are usually some cells in this area. In the anterior horn, cells are almost constantly present, either near the outer edge of

the base of the horn, or nearer the centre, but they are seldom grouped. They do not appear to be very much larger than the other middle cells.

There is no sign of any segmentation or regularity about the occurrence of the middle cells; they are typically casual, here one section, gone the next.

In size they vary somewhat, but seem to be pretty well of mixed sizes in all areas, and either polygonal or rounded polygonal in shape.

Other Cells :

Large posterior cells occur occasionally, but are rare; they may be on the outer side, or near the centre of the posterior horn.

Sizes :

Anterior Motor cells	.026 mm.
Large posterior cells	.025 mm.
Middle cells	.015 mm.

C 4 : 423 Sections. See Figs. 13-16

Shape :

The reticular formation, though still fairly large, is considerably less pronounced than in C 3, and the lateral horn becomes quite merged in the lateral enlargement of the anterior horn.

Middle Cells :

The notes made regarding these in C 3 practically all apply to this segment also. With the growth of the lateral motor nucleus, the middle cells do not occur in the outer aspect of the base of the anterior horn, though, in the upper part of the segment especially, they may be present between the motor groups. The middle cells seem to be rather more numerous than in C 3, and on the whole a little larger, particularly the more anterior cells; though here also the difference between these and the others is not at all marked.

Other Cells :

There is an occasional cell representing Clarke's column, and a few large posterior cells.

Sizes :

Anterior Motor cells	.027 mm.
Large posterior cells	.025 mm.
Clarke's column cells	.026 mm.
Middle cells	.016 mm.

C 5 : 412 Sections See Figs. 17-20

Shape :

Gradual increase in size of lateral enlargement. Reticular formation at same time becoming progressively less.

Middle Cells :

The middle cells show a distinct increase in number in descending the segment. Usually scattered at first, they have a greater tendency to occur in groups in the lower part. There are never very many anterior to the frontal plane of the central canal, although present both in the base of the anterior horn and, more rarely, between the median and lateral motor groups.

In the reticular formation, while it is well marked in the upper portion of the segment, the cells are usually scattered and sometimes lie well out into the white matter in its meshwork; in the lower portion there are more often distinct groups of cells. Central groups seem rather more frequent nearer the upper end than the lower. In the lower part of the segment there is often a well-marked band of cells stretching through the reticular and post-central areas to the central, or even to the para-central area. These may be aggregated into groups in any part of this region, but most often

post-centrally. Middle cells also occur in the region of Clarke's column, but not abundantly. But wherever they may be, the cells have always that feature of the middle cells - inconstancy of occurrence - being present in one site through very few sections. There is no trace of a regular segmentation.

As regards size and shape, the anterior cells are always fairly large and distinctly multipolar. In the other regions they are usually more mixed in size; the majority are probably as big as the anterior ones (and there are some occurrences of groups of large middle cells, not much smaller than the motor cells), but these are mingled with others, less in size. All are polygonal or rounded polygonal in shape.

Other Cells :

An occasional Clarke's column cell occurs, but these are rare. Large posterior cells are more numerous, although there are some considerable stretches without any occurring. Most often they are in the posterior part of the reticulum, sometimes in the post-central area or centre of the posterior horn. Two large cells observed in the anterior grey commissure, very close to the central canal.

Sizes :

Anterior Motor cells	.028 mm.
Large posterior cells	.025 mm.
Middle cells	.016 mm.

C 6 : 470 Sections. See Figs. 21-24

Middle Cells :

These cells are on the whole fairly numerous. In individual sections they may be few or many, scattered or grouped, but anywhere they are typically casual and of short-lived occurrence. The commonest position for a group is post-central, or about the junction of central and post-central areas (these are not very distinct in the cervical enlargement.) A reticular group is also common. Some cells in the position of Clarke's column are moderately common, but rarely a distinct group. In the base of the anterior horn, over against the lateral motor groups (and occasionally between them) middle cells are frequent, but rarely form a compact group; they are usually scattered.

In size the cells as usual vary considerably, but there is a distinctly large proportion of pretty big cells in this segment, not only anteriorly, but in the central and post-central regions also, where there are many quite as large and distinctly multipolar as anteriorly, although they are mingled with others smaller, and more rounded, polygonal in shape.

Other Cells:

There are only one or two cells which might represent Clarke's column.

Large posterior cells are fairly common, most often in the reticular formation, but also in the centre of the posterior horn and post-central area amongst the middle cells.

Two occurrences of large cells in the anterior grey commissure.

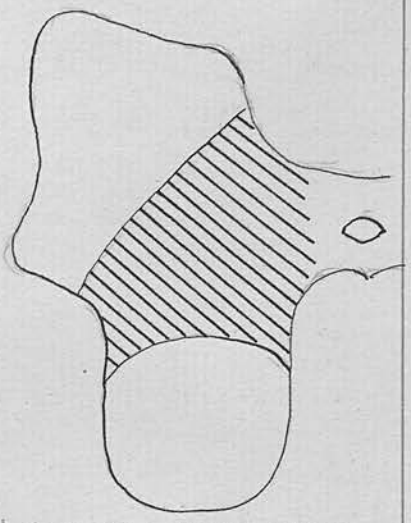
Occasional cells behind the area of Clarke's column, and in the base of the posterior horn, which it is difficult to classify: (middle cells or Waldeyer's posterior-basal cells).

Sizes :

Anterior Motor cells	.028 mm.
Large posterior cells	.027 mm.
Middle cells	.017 mm.

C 7 : 539 Sections. See Figs. 25-28.

Middle Cells :



May be found anywhere within the parts of the grey matter shaded in the diagram. This area is practically the same as in, say, the 2nd sacral segment but here the resemblance ends. They are by far the most abundant along a line from the reticular angle to the para-central area; (they are not found as a band like that in the sacral region); but as in the lower part of C 6, particularly in the post-central area. On the whole they are fairly numerous (though again not so abundant as in the lumbo-sacral enlargement). They may be scattered or grouped. Cells in front of the level of the central canal are fairly common, but not often forming a definite group. Para-central groups are moderately common, but as mentioned above, post-central ones are the most frequent, and these may extend into the central or into the reticular areas. In the region of Clarke's column they usually occur just as scattered cells, but cells behind the area of Clarke's column are not infrequent (middle cells or posterior-basal cells ?).

No trace of any segmentation or regularity of arrangement could be made out. In size and shape the anterior cells are generally fairly large and polygonal, the central and post-central large and medium sized, the reticular and posterior-basal cells more medium-sized, polygonal or rounded polygonal, although large cells may be found there also.

Other Cells :

Clarke's column cells increase in frequency of occurrence towards the lower end, occasionally two cells in one section. They often have a little cluster of middle cells around them.

Large posterior cells are also more abundant in the lower part of the segment. They may be on the outer aspect of the posterior horn or in the centre, and there are a few cells which it is impossible to say are large posterior cells or cells of Clarke's column.

Sizes :

Anterior Motor cells	.029 mm.
Large posterior cells	.025 mm.
Middle cells	.017 mm.

C 8 : 438 Sections. See Figs. 29-35.

Intermedio-lateral tract :

Appears first about the upper end of the lower fourth of the segment. It is situated on the postero-external aspect of the lateral enlargement on the extreme edge of the grey matter, or frequently on strands of grey matter lying a little way off the edge - just opposite the post-postero-lateral motor group of cells. At first there are just one or two cells; then there are sharply defined little groups of cells up to as many as twelve in number at the lower end of the segment. But the blanks between the cell-nests are longer than the duration of the groups. In size and character the cells are practically indistinguishable from the medium-sized middle cells.

Middle Cells :

In the upper part they are most numerous along the line from the reticular formation to the central canal; lower in the segment they diminish in number and tend to be more scattered, although little groups may be present in any of the usual areas. In the lower part they are found more between the median and lateral motor groups than in the upper part of the segment. As a whole the cells are fairly large, though the anterior cells tend to be rather bigger

than the more posterior ones. Cells are not more common in the reticular formation, and there, as in other regions, there is no sign of any segmentation or special grouping. There are only a few cells in the area of Clarke's column.

Other Cells :

Clarke's column cells are becoming distinctly more abundant. At the lower end there are often three or four cells in one section, but even there they are not present in every section.

Large posterior cells are fairly numerous, especially in the reticular area, also centrally in the base of the posterior horn.

Sizes :

Anterior Motor cells	.030 mm.
Clarke's column cells	.021 mm.
Large posterior cells	.025 mm.
Middle cells	.018 mm.
Intermedio-lateral tract (apical)	.016 mm.

D. I. 569 Sections. See Figs. 36-44

Shape of Grey Matter :

There is a marked change of shape in this segment as the post-postero-lateral group of motor cells, which is large at the upper end, and gradually dies out until there are only a very few cells representing it at the lower end. The lateral enlargement of the anterior horn almost disappears, only the posterior part of it merging into what is at the lower end of the segment the lateral horn proper.

Intermedio-lateral Tract :

At the upper extremity of the segment it is distributed on the posterior aspect of the anterior horn, a little internal to its tip, but with the gradual diminution of the lateral enlargement it appears to shift outwards so as, at the lower end, to lie quite at the tip of the lateral horn. At the upper end the cells occur in groups up to about a dozen in number and there are considerable stretches quite devoid of cells. These intervals gradually become shorter towards the lower end, but even there they are quite complete, i.e., there are short stretches where the tract is unrepresented. The groups at the lower end contain as many as 40 cells; they rise and fall rapidly in number and when at a maximum are spread over a considerable

area of the lateral horn. Outliers in the white matter just off the edge of the lateral horn are common. The cells may appear rounded, spindle-shaped, bipolar or definitely multipolar. They are very like the medium-sized middle cells in appearance. There is no indication of the reticular group in this segment; the cells occurring in the formatio reticularis belong to the middle cell system.

Middle Cells :

Cells of the bigger type occur particularly between the median and lateral motor groups of the anterior cornua; they naturally diminish in number towards the lower end of the segment. These bigger cells also are found fairly commonly behind the median motor groups (i.e., anterior central in position). The medium sized middle cells may occur in central, paracentral or post-central positions, also frequently in the formatio reticularis, and to a less extent behind the level of Clarke's column at the base of the posterior horn. The greatest development of them is just internal and a little anterior to the formatio reticularis. Here sometimes they seem to be almost constantly present, persisting through a number of sections, but enumeration shows nothing like a regular segmentation and they are never so closely packed or uniform in character as the cells of the intermedio-lateral tract. As a whole

the cells may be scattered thickly or thinly, or be grouped in any of the regions mentioned, but with the exception noted the presence of any particular group is always short-lived and erratic. The majority of the cells are of a polygonal or somewhat rounded polygonal outline, multipolar and very like those of the intermedio-lateral tract, so much so, that at minimal intervals of the latter it is impossible to say whether any particular cell near the site of the intermedio-lateral tract belongs to it or to the middle cells. Many of the post-central cells, behind and external to Clarke's column are of the small, more rounded type.

Other Cells :

Clarke's column : Cells not numerous nor constantly present. Even at the lower end there are gaps (in a longitudinal direction) without cells, but this is not a real segmentation. Several small groups of small cells in the posterior horn,- posterior basal and central posterior cells of Waldeyer, etc. Some of these behind Clarke's column which I have included as middle cells would probably correspond to Waldeyer's posterior-basal cells. Single large multipolar cells (large post-central cells) are not uncommon, chiefly in the reticular angle; also sometimes about the centre of the posterior horn.

Size of Cells :

Anterior Motor cells	.030 mm.
Intermedio-lateral tract	.018 mm.
Average middle cells	.018 mm.
Clarke's column cells	.028 mm.
Large post-central cell	.032 mm.

D 2 : 637 Sections. See Figs. 45-52.

Shape :

At the upper part of the segment the lateral horn still appears like a remainder of the lateral enlargement of the anterior horn; on the lower part it is quite distinctly marked off from the anterior horn.

Intermedio-lateral Tract :

The apical group forms a very constant feature and shows characteristic segmentation into distinct groups or cell nests with intervals between almost destitute of cells. The group is usually compact and lying at the tip of the lateral horn, sometimes also on the anterior aspect of the lateral horn, sometimes extending along the posterior aspect towards the re-entrant reticular angle. The cells are not very large, and are chiefly of a rounded polygonal shape. Maximum about 40.

A sudden commencement of the reticular group such as Bruce describes in his paper (p. 114) is not seen. In the upper part of the segment the presence of the reticular group is doubtful. There are cells present in the formatio reticularis, but indistinguishable in character from the middle cells. In the lower part, however, the reticular group is definitely present and readily recognisable as

composed of cells, larger than the apical cells, polygonal and not very much smaller than the anterior motor cells. In position they are found chiefly on the posterior aspect of the lateral horn, and sometimes stretching from there backwards around the reticular angle. The group is usually in contact with the apical group but distinguishable from it by the size of the cells. Numerically it is much smaller than the apical group (up to about 15) but the rise and fall of the two groups is exactly parallel.

Middle Cells :

The anterior cells are, as Waldeyer calls them, usually 'scattered' cells in the basal portion of the anterior horn. They are fairly numerous at times, forming small groups on either side of the horn ~~and~~ or in the centre of it. On the whole they are rather larger than the other middle cells, but they merge indistinguishably into the middle cells of the central region and cannot be definitely separated from them. These anterior cornual middle cells are not of so rounded, polygonal a shape as the others. They are usually more elongated in one direction, but the long axes may have any orientation. It is possible some may be really small motor cells.

The other middle cells may also be scattered quite irregularly either thickly or very few in number, but groups tend to occur in various positions.

These groups are never so compact as those of the intermedio-lateral tract, and in number run to about 6 or 10 cells - occasionally even 15 or 20. There is no sign of a regular segmentation, the characteristic feature seeming to be their casual occurence, i.e., a group suddenly appears in a certain position, may be traced through 2 or 3 sections, and then disappears altogether, or shifts to another situation. Groups may be traced from a central position through intermediate ones to practically any of the other typical sites, anterior, paracentral, postcentral or reticular. A central group is the most common, the next most frequent being post-central between Clarke's column and the formatio reticularis, and these are often difficult or impossible to distinguish from small cells in the position of Clarke's column (probably really middle cells, in the intervals of Clarke's column), and from cells still further back - the posterior basal cells. Particularly in the upper part of the segment there are fairly often cells in the reticular formation which from their size, character and casual occurrence are probably not cells of the reticular group but middle cells. The middle cells are very like the apical group cells in appearance and size, multipolar or rounded polygonal, though, more particularly in the lower part, some of them are larger polygonal, about as large as the

reticular group cells.

Other Cells :

Clarke's column is larger than in D 1, but still not numerically very large, nor are they present in every section. No segmentation, however. When its cells are not present, there may be small cells (middle cells ?) occupying its site. There are a few single large cells lying chiefly about the centre of the posterior horn.

Sizes of Cells :

Anterior Motor cells	.028 mm.
Clarke's column cells	.023 mm.
Large post-central cell	.021 "
Reticular group	.020 "
(large) Anterior middle cells	.018 "
Apical group	.014 "
(average) Middle cells	.014 "
(small) Posterior middle cells	.011 "

D 3 : 584 Sections. See Figs. 53-60.

Shape :

The lateral horn is a triangular wedge-shaped projection on the outer border of the grey matter - in the same frontal plane as the central canal. Its anterior border curves gradually into the outer border of the anterior horn, its posterior ~~horn~~ border slopes at first slightly backwards and then curves sharply at the reticular angle into the outer border of the posterior horn. The tip may be sharp, but is more often blunted or even rounded.

Intermedio-lateral Tract :

Its character agrees very closely with those described by Bruce, but with some additional features. Both apical and reticular groups are large numerically. The apical group may fill the whole tip of the lateral horn, and frequently extends along its anterior aspect, but rarely much on the posterior aspect. A few outlying cells in the white matter off the tip of the horn are common. The cells on the whole are rather larger than those in D 2, but are of the same rounded-polygonal type, and not staining very ~~clearly~~ darkly; towards the lower end there are often a few larger cells indistinguishable in appearance from those of the reticular group. Segmentation is very marked, but the minimal intervals are rarely quite distinct, a few

cells always remaining.

The reticular group is much bigger than in D 2. The cells are always distinguishable by their larger size (not very much smaller than the anterior-motor cells), and darker staining, although some are like the apical cells. They lie on the posterior aspect of the lateral horn; in the reticular angle; and also stretch inwards and forwards from the reticular angle almost to the centre of the grey matter. There are a few outliers in the white matter, outside the reticular formation. Segmentation is very distinct and its parallelism with that of the apical group is very striking, the maxima and minima being always at the same level, but unlike the apical group, in the intervals the cells are quite absent. Diagramatically it might be represented thus : ⟶

When the reticular group forms a band of cells extending inwards and forwards from the reticular angle, the cells are elongated along the line of the band, and when a group is waning, frequently some cells are left isolated in the centre; it may in fact be sometimes split into two parts, one on the posterior aspect of the lateral horn, the other in a central portion, where, if the group had not been traced serially they would certainly be taken for large middle cells.

In frontal longitudinal sections such a group would present all the characteristics described by Argutinski. At the maxima the apical and reticular groups are usually in contact, though distinguishable, but at least one cell mass occurs only in the central-reticular position and never lies in contact with the apical group.

Middle Cells :

As in D 2, there is no segmentation of these cells, irregularity of position and of duration being their characteristic feature. In some sections they are almost quite wanting, in others they are scattered irregularly, and in others they are grouped in various situations, the groups extending through only two or three sections in a vertical direction. The cells in a group are seldom so closely aggregated as those of the intermedio-lateral tract. In appearance the cells are mostly polygonal, about the same size as those of the apical group or a trifle larger, but staining rather darker; there are also some of the smaller rounded type, central or post-central in position, but they are not so common as in D 2. In the base of the anterior cornua they are more often scattered than grouped, and the size is not markedly if at all larger than the other middle cells, but in shape they are mostly more or less elongated in one direction, and not so nearly equal in different diameters.

Paracentral groups occur, but central and post-central groups are the most frequent, and in both of these latter positions it is often very difficult to say whether some cells belong to the middle cell system or to the reticular group of the intermedio-lateral tract, particularly when there are isolated central cells of the latter group. The relative sizes are not so very different as to be any absolute guide. In the intervals of the reticular cell nests some middle cells occur in the reticular formation.

Other Cells :

Clarke's column is still small and somewhat irregular in occurence. There are a few of the large isolated posterior cells, usually a little behind and internal to the reticular angle.

Some small cells on the inner side of, and others behind Clarke's column, which might be middle cells from their appearance, are perhaps some of Waldeyer's posterior basal cells.

Size of Cells :

Anterior Motor cells	.023 mm.
Large posterior cell	.023 "
Clarke's column cells	.020 "
Reticular group	.018 "
Apical group	.016 "
Middle cells	.016 "
Small post-central middle cells	.013 "

D. 4. 578 Sections. See Figs. 61-68

Intermedio-lateral Tract :

The apical group, more especially in the upper part of the segment, may frequently be divided into two sub-groups, one on the anterior aspect of the lateral horn, composed of smaller, more rounded cells, the other occupying the tip of the horn, of larger and more polygonal cells. Outlying cells are fairly numerous. On the whole, the group is a compact nest of cells but near minimal periods the cells are more loosely scattered. In the lower part of the segment, the cells are rather larger in size, are more polygonal and like the cells of the reticular group.

The reticular group may occur in an isolated central position, as in D 3, but the occurrence of this feature diminishes in frequency in a downward direction. The typical occurrence is as a band of cells stretching inwards and forwards from the reticular angle, and with the rise and fall of each group, junction with and separation from the apical group can generally be traced. In addition to this typical occurrence the cells may also be found as a somewhat loose clump in the reticulum; on the posterior aspect of the lateral horn, or sometimes extending behind the reticular angle on the outer aspect of the posterior horn. The cells are mainly

distinctly polygonal (multipolar) in shape, but when the group is in band-formation, they are drawn out along the line of the band. On the whole they are larger than the apical cells, but not uncommonly there is little difference in size, particularly in the lower part of the segment.

The tract as a whole may reach a maximum of over 50 cells in one section, and at maxima the two groups are about the same size numerically. Segmentation is occasionally a little erratic, sudden fluctuations in the number of cells occurring, but the type of variation is still the upper dorsal type, i.e., a pretty sudden rise and fall in numbers, with some but not many cells in the intervals. The tract is getting smaller numerically at the lower end of the segment. The parallel variation of the two constituent groups is very striking, but as before the segmentation of the reticular group is the more complete of the two.

Middle Cells :

The cells have the typical erratic occurrence of the system, if such it may be called. They may be few or abundant, scattered diffusely over the area not occupied by other groups (anterior motor, apical, reticular and Clarke's column), or in small clusters in various sites. Central grouplets are probably the most frequent, but paracentral and post-central ones

are also fairly common, although with the increasing size of Clarke's column there is not much room for post-central cells. The anterior cells are more frequently scattered than grouped.

The middle cells vary considerably in size, some being not much smaller than the motor cells, but most are about the size of the apical group cells and polygonal in outline. Amongst the post-central cells are more of the small, rounded type, and in the intervals of the reticular group these may also be seen in the reticular formation.

Other Cells :

Clarke's column is increasing in size; the cells are multipolar though frequently appearing to be rounded and bipolar; their nuclei are usually eccentric. In size they are not much less than the motor cells.

A few single, isolated, large multipolar cells are to be found in the posterior horn, mainly directly behind Clarke's column. There are also various small posterior basal cells, which often can not be separated from the post-central middle cells.

Size of Cells :

Anterior Motor cells	.025 mm.
Large isolated posterior cell	.021 "
Reticular group	.018 "
Apical group	.014 "
Middle cells	.014 "
Small post-central middle cells	.011 "
Clarke's column	.019 "

D. 5. : 741 Sections . See Figs. 69-76

Intermedio-lateral Tract :

The apical group cells lie typically at the apex of the lateral horn and along the outer part of its posterior border; in the upper part also fairly frequently on the anterior border, but rarely so in the lower part of the segment.

In both apical and reticular groups the cell clumps are less compact than in D 4, probably simply because there is more room, the cells being numerically fewer. In size there is not such a striking difference between the cells of the two groups, at maxima the reticular cells are undoubtedly the larger, but at other times there is little difference; the apical cells on the whole seem rather bigger than in D 4, and there are certainly fewer of the rounded type.

The characteristic appearance of the reticular group, at maximal periods is still a band of cells arching forwards and inwards from the reticular angle, but not extending so far centrally as in D 4, and there are seldom cells left stranded centrally. Towards the lower end the band shape is less frequent, the group being composed of rather more loosely scattered cells on the inner end of the posterior border of the lateral horn; partly also in the formatio reticularis

at the angle and sometimes extending a little backwards on the outer aspect of the posterior horn. Outlying cells are common; the majority belong to the apical group, but some, from their position in the white matter, probably belong to the reticular group. At maxima the cells are larger and more polygonal than those of the apical group, but when arranged in "band" shape, they are drawn out along the line of the band.

The segmentation of the tract is well marked, and is approaching the mid-dorsal type, i.e., the groups rise and fall in number more gradually, and do not attain such heights as in upper dorsal segments. The parallelism in variation of the two groups is almost perfect, and as before the division of the reticular group is sharper than that of the apical. At minima apical cells are never quite absent, but it is often impossible to be certain whether certain cells belong to the apical, reticular or middle cell systems. The junction and separation of the apical and reticular groups with their rise and fall in number is not quite so noticeable in this segment.

Middle Cells :

The anterior "scattered" cells are on the whole fewer than in D 4. In particular sections they may

be few or many, scattered or grouped; they have always a markedly polygonal shape, and at the various borders of their territory it may be difficult or sometimes impossible to distinguish them from, respectively, anterior motor cells, apical group cells, or reticular group cells. Nor do the other middle cells form a conspicuous feature of the ~~system~~ segment. Their occurrence is typically erratic and short-lived in any particular region (as studied serially). They may be disposed anywhere around the whorl of fibres surrounding Clarke's column, in front as a paracentral group, to the outer side as a central or post-central group. Some cells (posterior basal ?) also are seen lying directly behind Clarke's column. In the intervals of the reticular group, a few occur in the formatio reticularis. Most of the cells are polygonal in shape, though some of the post-central and reticular middle cells are of the small, rounded variety. Not always readily separable from reticular group cells, particularly when that group is not at its maximum.

Other Cells :

There are a few isolated large posterior cells, chiefly just behind the post-central middle cells, but they are neither very numerous nor strikingly

large. Some posterior basal cells, as mentioned above.

Sizes :

Anterior Motor cells	.023 mm.
Large isolated posterior cell	.022 "
Reticular group	.019 "
Clarke's column	.018 "
Apical group	.016 "
Middle cells	.014 "
Small (post-central) middle cells	.012 "

D 6 : 709 Sections. See Figs. 77-84.

Intermedio-lateral Tract :

The apical cells lie at the tip of the lateral horn and on the outer part of its posterior edge; there are sometimes a few on its anterior aspect, but not many. Outlying cells off the tip of the lateral horn are common, especially in the upper part of the segment and there are also a few outliers of the reticular group.

The reticular group is characteristically situated in the re-entrant reticular angle and on the inner part of the posterior border of the lateral horn, but not infrequently its cells also extend behind the angle on to the outer border of the posterior horn and in one or two groups extend as a short band in a central direction from the much angle. The cells of the two groups are often very alike in appearance, polygonal or rounded polygonal in shape, and also in size, although at maxima the reticular cells are distinctly larger, and they are more definitely polygonal in shape, but drawn out in an antero-posterior direction when on the edge of posterior horn or in a band in front of the reticular angle. A few of the large reticular type of cells are found at times in the apical group.

In number the tract has a maximum of about 50 cells at the upper end, but falling to 35 at the lower, and the apical is the larger group numerically. Segmentation is of the mid-dorsal type, and on the whole the oscillation of the two groups is parallel, but there are one or two instances of apical groups without accompanying reticular groups, and one occurrence of the reverse condition. The reticular group is as before more sharply segmented than the apical. When the cells of the two groups are similar in appearance, and the two lie in contact, it is impossible to define exactly the limits of each group.

Middle Cells :

Are not numerous in any part and have the characteristic erratic distribution and occurrence. They may be scattered or grouped; groups at base of anterior horn or centrally are probably most frequent. Para-central groups occur. With the increase in size of Clarke's column, there is not so much room for post-central cells, and when they are present it is often as a band on the outer aspect of Clarke's column and extending even round behind it; they seem to be more frequent at the level of the minima of the reticular group and may then also extend into the reticular formation. The middle cells

are very similar in size and appearance to those of the apical group and are not always easily separable from it or from the reticular group. The anterior cells are on the whole larger than the others, and the post-central smaller and more rounded than polygonal.

Other Cells :

The cells of Clarke's column vary considerably in number and even occasionally are quite absent for a short stretch, but enumeration through a considerable length revealed no definite segmentation.

A very few large isolated cells in posterior horn, chiefly just behind region of post-central middle cells.

Size :

Anterior Motor cells	.022 mm.
Clarke's column	.020 "
Reticular group	.019 "
Isolated posterior large cell	.019 "
Apical group	.016 "
Middle cells	.014 "
(Anterior	.018 "
Post-central	.012 ")

D 7 : 850 Sections. See Figs. 85-92.

Shape :

Lateral horn very small, and at minima of the intermedio-lateral tract may be practically absent.

Intermedio-lateral Tract :

The apical group is situated usually at the tip of posterior border of the small lateral horn, but occasionally pretty far forward on its anterior border. The reticular group is characteristically in the reticular formation, but when well developed, extends beyond this limit, either as a narrow band of cells stretching inwards and forwards from the reticular angle (such as it is) or, perhaps more commonly, backwards on the outer edge of the posterior cornu. There are outlying cells of both groups, but they are not numerous. The maximum of the tract per section in the upper part is about 30 cells, in the lower only about 25, and the apical group is somewhat the larger of the two. Segmentation is fairly well marked, and is characteristically mid-dorsal in type. The oscillation of the two groups is usually parallel, but there are one or two occurrences of small reticular cell nests without corresponding apical ones, and vice versa. The total number of cell-clumps is therefore about the same in each series, and there is never any

large collection of one group without the other at the same, or nearly the same, horizontal level. As before, the reticular group is more sharply segmented, the apical groups being longer vertically and not quite so conspicuous by their absence at minimal periods. Each group may be sharply defined as regards its limits but more commonly they are not very compact, so that the limits of each are not exactly definable. This difficulty of separation is increased by the similarity of the cells of the two groups to each other and also to the middle cells. In the majority of sections they are all of about one size and type (rounded polygonal). At maxima, however, the reticular group cells are generally distinctly larger than the apical, and in addition are often then grouped in band shape and drawn out along the line of the band (the line of the posterior horn outer edge); at those times they are more easily separable from other cells, although some at the anterior end of the band may be indistinguishable from middle cells; and it must be noted that cells of the size of the large reticular cells occur occasionally in the apical group too.

Middle Cells :

Appear to be relatively, though not absolutely abundant in this segment. They may be scattered or

grouped, and the groups are typically short-lived, seldom lasting through more than three consecutive sections. They may be anterior, central, paracentral or post-central. In appearance most of the cells are practically indistinguishable from the typical apical group cells and as mentioned under that heading cells on the border line often cannot be definitely placed on one or other system. The post-central cells which may extend round and to behind Clarke's column or in to the reticulum in the intervals of the reticular group, are frequently of the smaller and more rounded type. There seems to be some tendency to variation parallel with the intermedio-lateral tract; middle cells being more numerous at its maxima, but this is by no means invariable, as groups of middle cells are common enough even when there are very few intermedio-lateral tract cells.

Other Cells :

Only one or two large isolated posterior cells were observed, like anterior motor cells in appearance and lying in the position of the most posterior cells of the reticular group on the outer edge of the posterior horn.

Clarke's column is increasing in size, up to about 18 cells per section at times, although the

numbers vary considerably, but there is no real segmentation.

Size :

Anterior Motor cells	.024 mm.
Clarke's column cells	.019 "
Reticular group	.018 "
Apical group	.016 "
Middle cells	.015 "
Small rounded post-central middle cells	.012 "

Shape : Very little lateral horn, but rather more of one on the right side than on the left.

Intermedio-lateral Tract :

Has a maximum of about 30-35, of which the apical group forms rather the larger proportion. The apical group lies at the most prominent part of the outward curve of grey matter representing the lateral horn; it is not unfrequently just a strip of cells on the outer edge of the grey matter, on a frontal plane level with the central canal, or rather anterior to it. The reticular group is in the reticular formation, and from the shape of the grey matter this places it on the left side almost directly behind the apical group, on the right side behind and rather more internal. There are a few outlying cells of both groups. In the majority of sections the two groups are in contact, and often so close that it is impossible to recognise that they are two groups; in other cases two groups are recognisable, but cells at the junction cannot be definitely placed in one or the other. At minimal periods or when small, the groups may, on the other hand, be quite apart. The reticular cells fairly often extend backwards some way behind the reticulum on the outer edge of the posterior horn, and may also go a little way forwards and inwards from the reticulum. The cells are then drawn out along that line. In one instance the group extends far centrally, and dies out as an

isolated group of rather large cells in the central region. In character the cells of the two groups are in the main indistinguishable, - rounded polygonal cells, - also practically indistinguishable in appearance from the middle cells. Sometimes the reticular group is composed of distinctly bigger cells and, more rarely however, these bigger cells may occur in the apical group.

Segmentation is of the mid-dorsal type; the ebb periods of the oscillation are not very distinct. the variation of the two groups is usually parallel, but the maxima of the reticular group are generally at a slightly lower level than those of the apical.

Middle Cells :

Are fairly numerous, and with all the usual characteristics, erratic, irregular occurrence, scattered thickly or thinly, or grouped in any of the possible sites. They are polygonal or rounded polygonal in shape, practically identical in appearance with the cells of the intermedio-lateral tract and, particularly at minimal periods, not always sharply definable from the cells of the intermedio-lateral tract. There is definitely no variation in number corresponding to the variations of the inter-medio-lateral tract. Some of the anterior middle cells are not always distinguishable from the smaller motor cells.

Other Cells :

Clarke's column : maximum of about 18 cells; vary in number, but there is no definite segmentation. No large, post-central isolated cells noticed.

Size :

Anterior Motor cells	.021 mm.
Clarke's column	.020 "
Reticular group	.016 "
Apical group	.015 "
Middle cells	.015 "

D 9 : 699 Sections. See Figs. 101-108.

Shape :

Rather more lateral horn than in D 8. Its size varies with the size of the apical group really.

Intermedio-lateral Tract :

The apical group occupies the tip of the lateral horn, but often also stretches some way anterior to it. Sometimes the cells are all anterior to the tip. The reticular group is typically a clump of cells in the reticular formation, sometimes reaching inwards and forwards as a short band of cells, but more often extending backwards along the outer edge of the posterior horn. When large it extends outwards towards the tip of the lateral horn and becomes contiguous with the apical group. Outlying cells of both groups are present, but are not numerous. The maximum of the group is about 30, the apical being numerically rather the more important group. Segmentation is of the mid-dorsal type, and as before rather more complete in the reticular than in the apical group. The oscillations of the two groups are parallel and at the same level; although occasional small nests of reticular cells are present at minimal periods, they are always small and short-lived lengthwise.

The apical cells are sometimes small, rather rounded cells, perhaps especially when lying anterior

to the tip of the horn, but the majority are fair sized, rounded polygonal and practically indistinguishable individually from middle cells or from cells of the reticular group. The reticular group may be composed of cells the same size as the apical or (and just about as commonly) of cells some or all of which are distinctly bigger.

Usually the two groups are indivisable; sometimes two groups are quite recognisable, although cells at the boundary cannot be definitely assigned to one or other group; and at other times again the two are quite distinct and separate.

Middle Cells :

Are pretty numerous and of characteristic erratic and casual occurrence. No parallel variation with the intermedio-lateral tract. Most of the cells are rounded polygonal in shape and very similar to the apical cells, and not always sharply separable from cells of the intermedio-lateral tract. The anterior cells tend to be more elongated and distinctly multipolar, while the post-central, though sometimes fair-sized, are, perhaps more often than in any other segment, mainly of the small and more rounded type. These may extend round Clarke's column to almost directly behind it, and may be present in the reticular formation in absence of the reticular group.

Other Cells :

Clarke's column varies considerably in the number of cells, but there is no segmentation like that of the intermedio-lateral tract. No large posterior cells noted.

Size :

Anterior Motor cells	.023 mm.
Clarke's column	.021 "
Reticular group	.018 "
Apical group	.016 "
Middle Cells	.015 "
Small rounded middle cells	.012 "

D 10 : 573 Sections. See Figs. 109-116.

Shape :

The lateral horn is still a small blunted affair. Sometimes it lies considerably in front of the level of the central canal; the latter and the reticular formation being in the same frontal plane.

Intermedio-lateral Tract :

The apical group lies either at the apex of the lateral horn or, very often, quite in front of it. The reticular group is in the reticular formation, but may extend either backwards (a considerable way, sometimes), or outwards till in contact with the apical group - practically never inwards and forwards as a band of cells. Outlying cells in the white matter are rather more common than in D 9, particularly of the apical group.

Both groups are rather loosely bounded on their inner aspect often and cells on that boundary are often hard to distinguish from middle cells. The cells of both groups are alike in character and moderate sized, but especially at maxima and towards the lower end of the segment, reticular cells of the bigger type are more frequent.

The two groups are with about equal frequency, in contact and indivisible; and separate and clearly distinguishable. One or two good examples were noticed of parallel increase of the two groups,

becoming in contact at their maximum level and separating again as they died out. Segmentation at both upper and lower ends is regular and still of mid-dorsal type, but about the middle the cell occurrence is more erratic, clumps of cells and spaces without cells appearing to come irregularly and without parallelism between the two groups. The maximum of the tract is about 30, to which the two constituents contribute about an equal number of cells.

Middle Cells :

In the middle of the segment where the intermedio-lateral tract is poorly developed, the middle cells seem also to be rather fewer in number. Otherwise they are just as usual in their occurrence. They appear to increase in size a little towards the lower end and it is noticeable (in contrast to D 9) that the post-central cells in particular tend to be large and are often very hard to separate from the reticular group, which is not very sharply circumscribed on its inner aspect. But in general appearance and character, the middle cells are individually very like those of the intermedio-lateral tract.

Other Cells :

Clarke's column large; does not appear to vary so much in number in this segment.

A very few large, single, isolated posterior cells were observed, behind the position of the post-central middle cells.

Size :

Anterior Motor cells	.021 mm.
Clarke's column	.020 "
Reticular group	.015 "
Apical group	.014 "
Middle cells	.014 "

D 11 : 644 Sections. See Figs. 117-124.

Shape :

The grey matter begins to increase a little in size towards the lower end of the segment. The two sides are asymmetrical; on the right side there is practically no lateral horn, merely a slight protuberance of the grey matter; on the left side there is sufficient of a spike to make a distinct though widely obtuse angle where the reticular formation is. This asymmetry about the 10th and 11th dorsal segments is also noted by Dr. Bruce.

Intermedio-lateral Tract :

The tract has a mamimum of about 35 cells per section and though the reticular group is increasing in importance, the apical seems still to be somewhat the larger. Segmentation is pretty well marked, and is not now of the mid-dorsal type, the numbers rising and falling more rapidly. The two groups vary in a remarkably parallel manner and both last for about the same distances, the apical perhaps a little longer than the reticular and with not quite distinct intervals. The apical group on the left side lies usually at the tip of the lateral horn, about on the same frontal level as the central canal, sometimes a little in front of it; usually as a compact little nest of cells; on the right side this group is more strung

out as a band of cells on the edge of the grey matter, and may extend some way in front of the level of the central canal. On both sides the group may be split into two - an anterior and posterior division - particularly on the right. Outlying cells are not very common. The apical group is generally separated from the reticular; on the right side, indeed, it may be widely so; when in contact they are usually separable though occasionally not so. The cells are medium sized and vary like the middle cells. The reticular group cells are about equally often the same average size as the apical, and of larger size. They are frequently drawn out along the line of the group which is typically a short band of cells stretching from a little way behind the reticulum to a little way forwards and inwards from it. Sometimes it is just a clump of cells in the reticular formation, or, toward the lower end, a wedge with its base on the reticular angle and apex pointing inwards and forwards.

Middle Cells :

Anterior and central middle cells are frequent, either scattered or in small groups. They are polygonal, very like the intermedio-lateral tract cells, though, especially with the anterior cells, they tend to be more elongated and to have longer processes (at least as shown by this stain). The post-central cells

may be of the same type and hard to separate from the innermost cells of the reticular group, but a good many are smaller and more rounded. They may form a band on the outer aspect of Clarke's column, and there are pretty commonly cells directly behind Clarke's column which may be middle cells or Waldeyer's posterior-basal cells.

The middle cell occurrence is everywhere of typical erratic and casual character.

Other Cells :

Clarke's column - maximum now up to about 30. Variation in numbers not very great.

Single large, isolated cells, just behind the posterior middle cells are rather more common.

Sizes :

Anterior Motor cells	.023 mm.
Clarke's column	.021 "
Reticular group	.017 "
Apical group	.016 "
Middle cells	.016 "

D 12 : 454 Sections. See Figs. 125-132,

Shape :

The lateral horn forms a pointed broad-based wedge with a long sloping posterior border. There is frequently this difference between the two sides; viz. that on the right the lateral horn (and apical group) is further forward than on the left side.

Intermedio-lateral Tract :

The parallel oscillation of the two groups is well marked. The groups now rise and fall rapidly in number. As elsewhere the reticular group is rather more sharply segmented than the apical. The maximum is about 50 and when at this height the reticular group is now definitely rather larger numerically than the apical. The apical group may form a sort of wedge of cells in the lateral horn, or, especially on the right side, an antero-posterior band, and here also it occasionally tends to be split into two sub-groups, but not so frequently or definitely as in D 11. Outliers in the white matter are pretty common. It is generally some distance anterior to the reticular group and even when in contact with it is usually easily distinguished. Sometimes the cells of the two are alike in size, but as a rule the apical cells are smaller than the reticular, more like the middle cells, and not always clearly defined from them on the inner

aspect. The reticular group may be present as a wedge of cells or as a band stretching both backwards from the reticulum and forwards and inwards, sometimes well towards the central region. Occasionally it is separated by a distinct cell-less area from the edge of the grey matter, but not so distinctly as in L 1. As with the apical group, it is not always sharply distinguished from middle cells on its inner aspect.

Middle Cells :

The remarks made under D 11 apply to this segment also. Post-central groups are not so common; there is little room for them with the great growth of Clarke's column, but still small groups are fairly common, both of the ordinary type and of the small rounded type.

Other Cells :

Clarke's column is large, although on one side for quite a number of sections it was noticed to be almost entirely lacking.

Isolated, single, large posterior cells are becoming rather more frequent.

Cells behind Clarke's column (middle cells or posterior-basal cells) are also fairly common, though never abundant.

Sizes :

Anterior Motor cells	.024 mm.
Clarke's column	.023 "
Large posterior cells	.020 "
Reticular group	.018 "
Apical group	.016 "
Middle cells	.015 "

L 1 : 595 Sections. See Figs. 133-140.

Shape :

Grey matter increasing in size. The lateral horn is merely a rounded projection, with sloping posterior border, and the reticular angle is a very obtuse one.

Intermedio-lateral Tract :

The apical group is situated about the outermost part of the projection representing the lateral horn, about the same frontal level as the central canal or more anteriorly. It never attains greater size than about 15 cells in one section, being numerically much less than the reticular group which reaches to about 25. The occurrence of the latter is typically as a wedge of cells with base on the reticular angle and apex centrally. The base may be lengthened out either towards the lateral horn or along the posterior horn; in the latter case the shape of the group is more like the familiar band. Very commonly the wedge or clump of cells at the reticular angle is not actually on the edge of the grey matter, but a little way internal (and it may be pretty far centrally), a strip of grey matter destitute of cells intervening between the groups and the white matter. This condition recalls the similar state in D 4 and, especially, in D 3. Segmentation

of the two groups shows a good parallelism, but now the reticular groups are longer than the apical as well as numerically larger at maxima; the rise and fall of groups, though fairly rapid even at the upper end, is much more sharp at the lower end. The two groups are generally apart and also generally fairly compact; only on their inner aspects is it sometimes difficult to be certain whether certain cells belong to the tract or to the middle cells.

The apical cells vary considerably in size, - small rounded, moderate, and large polygonal, but on the whole are considerably smaller than the reticular, which are large, dark-staining, polygonal cells, sometimes elongated along the line of the band. At minimal periods there may be some loosely scattered cells impossible to allocate with certainty to either group of the tract or to the middle cells&

Middle Cells :

Like other cells, these have also increased in size in this segment. Anterior cells are particularly numerous; they may be as groups in various parts of the base of the anterior horn, or very commonly are thickly scattered over it. They are not always distinguishable from small motor cells. The central middle cells are also common, and of typical middle cell character as regards occurrence. Both they and

the anterior ones are polygonal cells, very like the intermedio-lateral tract cells in appearance individually, and as mentioned above not always exactly separable from the tract when near its boundaries. Post-centrally they are mostly also of the same type, but both here and occasionally in the reticulum are some of the smaller, more rounded cells.

Other Cells :

Clarke's column is a large group, averaging 15-20 and up to 30 sometimes. Large single isolated posterior cells are much commoner than in higher segments, chiefly in the post-central region or further posteriorly; sometimes also in posterior part of the reticulum.

Sizes :

Anterior Motor cells	.025 mm.
Clarke's column	.027 "
Reticular group	.020 "
Apical group	.016 "
Middle cells	.018 "
Large posterior cell	.027 "

L 2 : 648 Sections. See Figs. 141-148.

Shape :

At the upper end there is a prominence representing the lateral horn, but this does not last very long. About the middle, with the appearance of the antero-lateral motor group there is an added prominence to the anterior horn. There is then just a slight dip inwards of the outer edge of the grey matter at the angle of the reticular formation.

Intermedio-lateral Tract :

At the upper end the tract still numbers about 40 at maxima, in the proportion of apical 15, reticular 25. At first there are regular little apical groups, at same levels as the reticular ones, though not lasting quite so long as the latter (and even they are very short) but by the middle of the segment there are practically no apical groups, just a few scattered cells on the edge of the grey matter a little anterior to the reticulum, and occasional outliers in the white matter. Even to the lower end there are a few cells which are probably apical group cells, though it is quite impossible to be certain that they are not anterior middle cells.

The reticular group occurs as distinct cell-nests quite to the lower end of the segment, though steadily diminishing in number. They rise and fall

in number very abruptly, are short-lined, and the intervals between them are usually complete. They may form either a band or a wedge at the reticular angle, and very often are placed some way internal to the edge of the grey matter. The apical cells are always smaller than those of the reticular group, and generally rather less also than the anterior middle cells. The reticular cells are good sized polygonal cells, sometimes elongated in line of band. In the lower half they are not always very easily distinguishable from middle cells, though they are generally more darkly stained.

Middle Cells :

There is a large increase in number corresponding with the increase in size of the grey matter, and many of the cells are also larger. They are polygonal, multipolar cells, often with fairly long processes, not as a rule, however, staining quite so darkly as the reticular group cells. In the basal and inner portions of the anterior horn and in the central region they may be at times almost quite wanting; at others few and scattered irregularly, or again thickly distributed over the area or grouped in almost any part more or less closely. They may be present in the area corresponding to the position of the apical group, and as mentioned, not always

distinguishable from it, and in the upper half may apparently even extend to the margin of the grey matter between the apical and reticular groups. They may also be present in the region sometimes occupied by the central end of the reticular group, and there is then some difficulty in allocating some of the cells to their proper system. Post-centrally the small rounded cells are not very common; still, small groups do occur, sometimes as a sort of band round the outer side of Clarke's column. Most of the post-central cells are polygonal cells, just like the central and anterior ones, but even these are generally smaller.

Other Cells :

Clarke's column gradually diminishes in numbers, but even at the lower end there are 8-12 cells. As elsewhere it varies, but shows no regular segmentation. There are several occurrences of outlying cells in the posterior columns.

Large posterior cells, almost identical in appearance with motor cells, are frequent. Usually single, but sometimes 2 or even 3 in one section. They may be almost in the central region, post-central or behind the reticulum on the outer side of the posterior horn.

There are posterior basal cells similar in appearance to middle cells.

Sizes :

Anterior Motor cells	.025 mm.
Clarke's column	.027 "
Reticular group	.020 "
Apical group	.018 "
Middle cells	.018 "
Large posterior cells	.025 "

L 3 : 571 Sections. See Figs. 149-156.

Shape :

Marked growth in size of anterior horn; outer border at upper end is almost antero-posterior, at lower goes backwards and inwards to the reticular angle. No true lateral horn.

Intermedio-lateral Tract :

In about the upper fourth or fifth there are still some cells situated in the reticular formation apparently belonging to the reticular group, but they are very few in number and rather scattered casually than in definite small groups, as at the commencement of the tract in C 8. It is not easy to distinguish them from middle cells. This method of termination of the tract agrees with that found by Dr Bruce.

Middle Cells :

These are a striking feature of the sections. They are numerous and may be present anywhere in the posterior part of the anterior horn, central area and base of the posterior horn. They have also invaded the area occupied at higher levels by the reticular group and by the cells of Clarke's column, although in the latter position they are never very numerous. They may be scattered thickly over this wide area or there may be only very few cells in some sections. Groups or

thicker aggregations of cells may be seen in the anterior, central, para-central, post-central or reticular regions, but as at other levels these groups are never of longer occurrence in one site than through 3 or at most 4 sections.

Reticular groups are not more frequent than others, and these groups have none of the character of the intermedio-lateral tract groups, but all those of the middle cells (e.g., as regards segmentation, staining of cells, closeness of clumping).

In size and shape there is great variation. Many are large cells (bigger than intermedio-lateral tract cells) polygonal and with long processes but not staining so dark as the motor cells generally. The post-central cells are on the whole smaller and more rounded, but are by no means all of them so. Quite a fair proportion are as large and distinctly multipolar as the more anterior ones.

Other Cells :

Clarke's column at the upper part of the segment consists of 6 or 8 cells usually, but at the lower end it has fallen to 1 or 2 cells, and these only at intervals - not constantly present.

Large isolated cells - very like the motor cells - in the posterior cornu are common, singly

or sometimes two or even three in a section; usually in the middle of the horn, not uncommon on the outer border (reticular or post-reticular), rarely in the inner border. There are also small posterior basal cells.

Sizes :

Anterior Motor cells	.031 mm.
Clarke's column	.029 "
Large posterior cells	.025
Middle cells	.020 "
Reticular group	.018 "

L 4 : 444 Sections. See Figs. 157-160.

Middle Cells :

The description given of L 3 practically applies identically to this segment also. In the lower part the cells seem to be extending rather further forwards on the median aspect of the anterior horn. In the reticular formation there are usually a few cells, but groups are rather rare.

Other Cells :

In the upper half of the segment, single cells of Clarke's column occur at intervals, but in the lower half they are practically absent.

Large posterior cells, as in L 3, are seen fairly frequently and are perhaps most often on the outer side of the posterior horn.

Size :

Anterior Motor cells	.031 mm.
Large posterior cells	.029 "
Clarke's column	.027 "
Middle cells	.020 "

L 5 : 498 Sections. See Figs. 161-164.
(As noted previously, this segment was taken from a different cord).

Middle Cells :

Their character, distribution and arrangement are practically the same as in L 3 and L 4. In various sections they may be few or many in number, scattered or aggregated in any of the situations mentioned under L 3. There is no special reticular group more than any other. They extend fairly far forwards in the outer part of the central region, though not so much so as in the lower part of the segment since the motor cells (post-postero-lateral group), are further back, almost on the same frontal levels as the central canal. They vary greatly in size, the larger being about the same size as the smaller motor cells, but many are considerably smaller and more rounded in outline. They stain paler than the motor cells, however.

Other Cells :

Cells of Clarke's column are present as single (or even two or three) cells pretty frequently in the upper part, but getting progressively fewer and at longer intervals, and are quite absent in the lowest third.

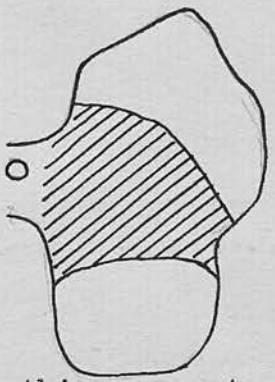
There are occasional large isolated cells in the posterior horn near the centre or on the outer border, but they are not nearly so frequent as in L 4.

Sizes :

Anterior Motor cells	.03± mm
Clarke's column	.030 "
Large posterior cells	.026 "
Middle cells	.020 "

S 1 : 366 Sections. See Figs. 165-168.

These are present pretty much as in the lower lumbar segments. They may be scattered or grouped; there are sometimes few present, but more often they are comparatively numerous, and may be anywhere within the part shaded in the diagram. In the Clarke's column area they are fairly common, though not so abundant as in other parts and never forming a very marked group there. There is a marked extension forwards of their area of distribution in this segment correlated with the absence of anterior median motor cells, so that the middle cells may extend almost to the antero-internal angle of the anterior horn and in the anterior area they may be very abundant. In the reticular area they seem rather to increase in number towards the lower end, but in appearance and in occurrence the cells there are in nowise different from the other middle cells. The middle cells as a whole are fainter staining than the motor cells. In shape they are usually distinctly polygonal and multipolar with distinct processes, and varying considerably in size.



Other Cells :

Clarke's column is quite unrepresented. Large posterior cells occur fairly often in almost any part of the posterior horn, but especially in the reticular area; also amongst the post-central middle cells.

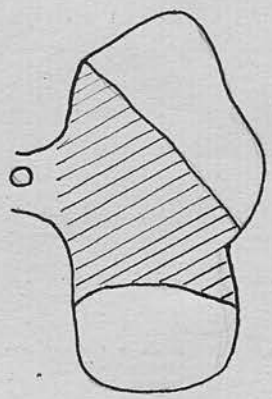
Sizes :

Anterior Motor cells	.035 mm.
Large posterior cells	.030 "
Middle cells	.020 "

S. 2 : 315 Sections. See Figs. 169-172.

Middle Cells :

These occur under conditions similar to those in S 1., amd over the same big area of the grey matter, indeed over rather more of it proportionately, extending rather further forwards and relatively further outwards in the anterior horn, as the lateral enlargement is not so great as in S 1. Diagrammatically their area of distribution may be shown thus; anywhere within the shaded area. Although individual sections may be picked out with very few cells, they are on the whole very abundant. In size they vary considerably. They may be scattered diffusely or aggregated into groups in almost any part of the area, but anterior, central, and reticular are perhaps the most common, but in none of the areas have the cells any features different from the cells of the others. All are much alike in size, appearance and irregularity of occurrence.



Other Cells :

Large posterior cells occur in almost any

part of the base of the posterior horn, but most often near its outer margin.

Sizes :

Anterior Motor cells	.038 mm.
Large posterior cells	.025 "
Middle cells	.020 "

S 3 : 266 Sections. See Figs. 173-176.

Intermedio-lateral Tract :

See under S 4.

Middle Cells :

Area of occurrence practically the same as in S 2. In this segment also they are numerous, but towards the lower end are becoming less so; there they only occur thickly in the basal part of the anterior horn. The anterior and central cells are on the whole larger than those in other parts, especially the anterior, which sometimes can hardly be distinguished from motor cells. In the reticulum they are usually only moderate sized, but otherwise not different from elsewhere. Distinct groups are not now so common in any part; the cells are at places rather thickly scattered than grouped.

Other Cells :

Large posterior cells are of fairly common occurrence. Posterior marginal cells seem to be more frequent than usual, i.e., cells on outer edge of posterior horn well behind the reticular formation.

Sizes :

Anterior Motor cells		.032 mm.
Large posterior cells		.031 "
Middle cells :	anterior	.023 "
	others	.016 "

S 4 : 284 Sections. See Figs. 177-182.

Intermedio-lateral Tract :

In the extreme lower end of S 3 (but as explained on p. 19)the limits of the lower sacral segments may not be quite accurate) and in the upper part of S 4 there begin to appear in the formatio reticularis a fairly prominent group of cells different in character from the middle cells. They are much smaller, more rounded and paler, and in fact seem to consist mainly of nucleus, there being very little surrounding cytoplasm. At first they show a sort of segmentation, the group being present for perhaps four or five sections, then disappearing for a little, but soon they become practically constantly present as a clump or wedge in the reticular angle. All the cells in the reticulum are rarely however of this type; usually they are mingled irregularly with others indistinguishable from the ordinary middle cells, sometimes the one set, sometimes the other predominating. It was found impossible to count these small cells separately, but although they were not constantly present, they did not give the impression of having a regular segmentation such as occurs in the intermedio-lateral tract of the dorsal region of the cord.

Middle Cells :

With the gradual dying out of the motor groups, the middle cell area extends pari passu until at the lower end of the segment they are found over the whole of the anterior cornua as well as within their more usual limits. But at the same time they become progressively fewer in number and also smaller in size. They are more often scattered than very definitely grouped, and though they may be in almost any part, they are more abundant in the anterior cornu, and here also they are on the whole larger than in the central and more posterior areas. As mentioned, there are cells in the reticulum mixed with those of the intermedio-lateral tract, indistinguishable in every way from the other middle cells. In character and irregularity of occurrence the middle cells are as in other segments.

Other Cells :

Large posterior cells are fairly common and may occur in almost any part of the base of the posterior horn. Posterior marginal cells seem also rather numerous.

Sizes :

Anterior Motor cells	.030 mm.
Large posterior cells	.027 "
Middle cells : anterior	.020 "
Middle cells : others	.016 "
Intermedio-lateral tract (reticular group)	.010 "

S 5 : 274 Sections. See Figs. 183-186.

Intermedio-lateral Tract :

As in the lower part of S 4, small round pale cells are almost constant in the reticular area, and may be traced practically to the extreme lower end of the segment, though in greatly diminished numbers. They are mingled with cells indistinguishable from middle cells, but generally speaking the small cells tend to be rather grouped posteriorly to the larger ones. These cells are circular, oval, or rounded with as a rule no processes or chromatin to be made out, but in a few, faint cell-outlines can be discerned, though the majority look as if they consisted simply of the dark stained central nucleolus and the round clear nucleus.

Middle Cells :

Gradually diminishing in number till at the lower end they may be described as only very ~~diminished~~ occasional in occurrence. They may be in any part of the grey matter, but tend to be chiefly in two places, firstly in the extreme anterior part of the anterior horn, secondly near the reticular angle; the former are generally larger in size.

Other Cells :

In the upper half an occasional anterior motor cell is still present. A few large posterior cells also occur.

Sizes :

Large posterior cells	.026 mm.
Middle cells	.015 "
Intermedio-lateral tract (reticular group)	.010 "

Coccygeal Segment : 273 Sections. See Figs. 187-188

At the upper end there are some straggling middle cells both anteriorly and near the reticulum, but they become fewer and fewer down the segment. Some of the intermedio-lateral tract cells seem also to be present, as are a few large posterior cells.

Sizes :

Middle Cells	.014 mm
Large posterior cells	.025 mm.

SUMMARY.

The results of the examination of the various segments of the cord may now be summarised under the headings of the different cell groups examined.

Intermedio-lateral Tract :

Upper Cervical Region :

This tract is recorded as occurring in the upper four cervical segments (Bruce, p. 127). I have not been able to identify it in this region. Small polygonal cells certainly do occur in the lateral horn of these segments and also in the reticular formation, but in practically no way do these cells differ from the middle cells - I mean from the middle cells in their more typical central position. In appearance the cells are identical, and there is nothing to suggest the characteristic segmented arrangement of the intermedio-lateral tract of the dorsal portion of the cord. On the contrary the cells are few in number and of irregular occurrence like that so typical of the middle cells. The only point at all suggestive of the intermedio-lateral tract is that some cells appeared to lie out free in the white matter, but this may be illusory. The reticular formation is very large and undoubted middle cells occur far out on its strands. Very possibly those that appear to be free in the white

matter are really in the fine reticular meshwork which is not shown up particularly well by the stain employed. I cannot agree with Waldeyer that the cells found in the lateral horn and in the reticular formation belong to the same series as the Seitenhornzellen (apical and reticular) of the dorsal cord simply because of the analogy of position : firstly, because middle cells may be found in these positions even in the dorsal region, and secondly, because the intermedio-lateral tract of the dorsal region has been proved to have such a very sharp upper limit - the reticular group in D 2 and the apical in C 8.

A few larger cells found in the lateral horn may possibly be part of the spinal accessory nucleus, but these large cells are of such comparatively rare occurrence that it seems more probable that they are only rather large middle cells.

The tract is certainly not represented in C 5, C 6 and C 7.

Lower Cervical, Dorsal, and Upper-Lumbar Regions :

In this portion of the spinal cord the features of the intermedio-lateral tract have been found to confirm very remarkably those described by Bruce. (I would like here to state that, in order to avoid any bias I wrote my descriptions of all the segments before looking up his account of the tract for details). All the characteristics need not be

detailed as they are given so fully in his paper, but I might refer to some small points of difference or additional features that have been brought out. The two component groups (apical and reticular) are easily recognised. The cell groups are arranged in a manner fairly characteristic of each segment, and although this arrangement is not always exactly the same as that described by Bruce the differences are slight. Probably they vary somewhat in every individual and the difference in shape between the cord of a new-born child and that of an adult must also be taken into consideration. The upper limit of the apical group is identical with his; also that of the reticular group, although it was not found to begin so sharply. The lower limit of the apical group is found to be about the middle of L 2, while the reticular group can be traced rather more definitely than in Bruce's case into the upper part of L 3. The segmental character, parallel oscillation of the two groups, mode of rise and fall in numbers, sharper segmentation of the reticular group, approach and separation of the two groups have been found to be practically identical with Bruce's description. The central position of the reticular group sometimes and its occurrence quite internal to the edge of the grey matter (see particularly D 3 and L 1) may be noted as a new feature observed. In the adult cord, Bruce

found it impossible to distinguish definitely the cells of the two groups in form, size and structure, although noting that large cells appear to be relatively more numerous (in both series) in the lower end of the tract. In the present instance I have found that although many of the cells are alike in size, those of the reticular group are on the whole so constantly rather larger as to suggest that they may be functionally different. The average cell diameters seem to be about .018 mm. for the reticular cells and .016mm. for the apical. These are approximately average figures for the whole length of the tract. Much larger individual cells may be found in either group, but I think the extreme size of the reticular cells considerably exceeds that of the apical. Only in the mid-dorsal region (particularly about D 8) is there very little difference in size between the two sets of cells.

In appearance the cells may be looked upon as slightly modified smaller editions of the anterior motor cells. They are multipolar, although sometimes from the cells being elongated in a particular direction they may appear to be bi-polar. Many are distinctly polygonal with distinct processes and concave borders between the angles formed by the projecting processes; in others, particularly the smaller apical cells, the polygonal shape is not so

distinct, the whole outline is more rounded; those I have described as "rounded polygonal." In the reticular group the cells are frequently polygonal, but many are elongated along a line running forwards and inwards from the reticular angle and their shape is then more spindle-shaped or fusiform. The cells have a clear circular nucleus with central dark-staining nucleolus. The nucleus may be so large as to take up almost the whole width of the cell, although in the reticular group and especially in the more definitely polygonal cells there is usually a band of protoplasm between the nucleus and the cell border. The nucleus is usually central in position, but a considerable number have been observed with the nucleus lying eccentrically, either rather to one edge of the cell, or in the case of the fusiform cells nearer to one end.end. Cajal, I think, has figured growing nerve cells with eccentric nuclei, so that this may quite well be a normal and not a pathological feature. The chromatin granules are arranged somewhat after the manner they are in the motor cells, i.e., in rings parallel to the cell outline, but in the case of the intermedio-lateral tract there is not the same regularity or abundance of granules. Not infrequently when the nucleus occupies the whole width of the cell, the chromatin may form simply two clumps near either pole of the cell.

Lower Sacral Region :

In the lower lumbar and upper sacral regions the intermedio-lateral tract is not represented. Certain cells found in the reticular formation are not regarded as belonging to it, but to the middle cells,— for reasons similar to those given regarding cells in the like position in the lower cervical segments. But in the lower part of S 3, and in S 4 and S 5, there is found in the reticular formation a different type of cell, which I take to represent the intermedio-lateral tract. Their vertical distribution corresponds very nearly with that of Langley's Sacral Autonomic System, and if, as seems most probable, the intermedio-lateral tract of the dorsal region is the spinal centre of the dorsal sympathetic then these cells may very likely be the centre for the sacral autonomic system (nervi erigentes, etc), although direct proof of this is not yet forthcoming. At their upper limit there appears to be a segmented character analogous to that in the dorsal region. Then they become practically constantly present as a cell group near the reticular angle. They do not form a very distinct and separate group, but are mingled with other cells - apparently belonging to the middle cells. In appearance they are quite different from the dorsal intermedio-lateral tract

cells, being much smaller (average diameter about .010 mm.), circular or oval, and consisting almost entirely of a clear nucleus with central dark nucleolus. There seems to be almost no surrounding cell protoplasm, and no chromatin granules, and cell processes could not be made out.

Middle Cells :

The middle cells are present throughout the whole length of the spinal cord. They are situated in the middle region of the grey matter between the free anterior and free posterior cornua, but they sometimes also extend into the region usually occupied by the anterior cornual cells, by the intermediolateral tract or by Clarke's column. The small cells in the base of the anterior horn ("scattered cells") cannot be sharply separated from the middle cells, nor can some of the small cells about the base of the free posterior horn.

Although some cells may be found in all the areas at practically any level in the cord, there are certain arrangements which may be looked upon as typical for each segment, or at least for each region of the cord. In the upper cervical region they are not on the whole very abundant, (thus differing somewhat from Waldeyer's description) but are best developed in the central and para-central fields. In the cervical enlargement they are much more numerous and particularly ~~with~~ within a broad band extending

from the formatio reticularis about to the anterior grey commissure.

Throughout the dorsal region they are again comparatively few in number and may be scattered irregularly, but small groups are often found, most commonly in the central and post-central areas.

In the lumbar segments the middle cells are abundant, particularly centrally and in the base of the anterior horn. Their field has also extended until in the lower sacral they come to be found over the whole area of the anterior cornua in addition to their more usual situations.

At all levels, as studied in serial sections, the distribution of the middle cells is seemingly erratic and casual. No regular plan can be made out, and there is most certainly no segmentation like that so well seen in the intermedio-lateral tract. The cells are sometimes just dotted here and there singly; sometimes they are scattered fairly thickly and evenly over the whole or part of the regions they are to be found in; or again they may occur more thickly in one part or be aggregated into a distinct little cell group or nest, but even then these cell groups are seldom so closely packed as are the cell groups of the intermedio-lateral tract. The duration of any one of these types of cell arrangement

is inconstant, and although there are levels where cells seem for a bit to be almost persistent in one place, this much can be stated as a general rule, that no middle cell group lasts through more than a few serial sections. If traced further the group is found either to shift to some other area, or to die out altogether. Occasionally there appears to be a variation in number of cells parallel with the oscillations of the intermedio-lateral tract, but closer study shews that this is by no means absolute and is probably only a local accidental variation.

Without expressing any opinion as regards function, I am inclined to divide the cells I have described collectively as middle-cells into three groups, basing this division merely on the distribution and arrangement of the cells and on the microscopic appearance of the cell-bodies. These divisions are, however, not very sharply defined either as regards the character of the individual cells or in the cell distribution. Still they seem to warrant such a ~~distribution~~ division being made, and to suggest at least that the cells of the three groups are functionally different. The groups I would make are :

(1) The middle cells proper, occurring chiefly in the central area. These cells are of medium size and very similar to those of the apical group of the intermedio-lateral tract, multipolar, polygonal or

rounded polygonal in shape, with a comparatively large nucleus and a few chromatic granules round it in the cell substance. Sometimes scattered, but very often they occur as a small clump of cells. With them may be included the cells in the para-central area which, although sometimes forming a distinct and separate group, can very often not be separated off from the central cells.

Many of the cells occurring in the reticular area at levels where the reticular group of the intermedio-lateral tract is not present (especially in the lower cervical region) may probably also be included here.

(2) Anterior central cells in the base of the anterior horn - one of Waldeyer's "scattered" cell groups. As this name implies, these are often simply scattered over the area in question, but sometimes they are aggregated into small cell-nests, but rarely very compact ones. Although there is no sharp boundary posteriorly between them and the central cells, they are in the main larger cells and are further distinguished by their shape. They are not so often definitely multipolar and of approximately equal diameter in different directions, but more frequently appear to be bipolar, with long-drawn-out processes. The axis of elongation may be variously oriented.

With these would fall to be included the middle cells in the external central area of the lateral enlargements, particularly in the sacral region of the cord. Possibly also some of the paracentral cells should be classed here and not in the previous group.

(3) Post-central cells. These lie in the area between Clarke's column and the formatio reticularis, or in the corresponding region of the grey matter at levels where Clarke's column is unrepresented. As with the anterior cells, there is no sharp boundary between this series and the central middle cells. They are often continuous, or the cells may lie betwixt and between the two areas. But although many cells may be as large, they are distinguished on the whole by being smaller in size than the central cells and less definitely polygonal, more rounded in shape. They are generally present either as a small clump of cells, or as a band of cells on the outer and posterior aspects of Clarke's column. Posteriorly it is very difficult to separate this group from the posterior-basal and posterior-marginal cells of Waldeyer.

With this division may be included the small cells present in the area of Clarke's column, particularly when that column is absent or only represented by casual cells. Also some of the small cells found in the reticular area, especially those between the nuclei of the reticular group of the intermedio-

lateral tract. These subdivisions of the middle cells may require modification by other methods of investigation, particularly by tracing the course and termination of the cell processes. I have attempted to do this by means of Cajal's silver impregnation methods but have not succeeded. All I can affirm is that the fibres arising from the middle-cells run from the cells in a variety of directions to begin with but as some could be traced far enough to be seen doubling more or less sharply upon themselves this gives no real clue to their destination. In no case could I follow any one to a termination. The fibres from the intermedio-lateral tract cells appeared to run, ~~more often~~ some of them, in the direction of the anterior cornua, others, out into the lateral white columns of the cord. In some, at all events, both of the middle cells and of the intermedio-lateral tract cells there was observed an endocellular fibrillary network similarly to that in the large motor cells of the anterior column.

Clarke's Column :

Represented by occasional single cells in the cervical portion of the cord. These begin in C 7 to be more numerous and to be present at shorter intervals; this process continues till in D 2 the column becomes a continuous one. It gradually increases in number of cells reaching a maximum about

D 12 or L 1 then dies away gradually in L 2 and L 3 till in L 4 and L 5 it is ~~separated~~ represented only by occasional cells at intervals. It is not present at all in the sacral region. Although the numbers of the cells vary considerably from section to section yet enumeration reveals no true segmentation such as is found in the lateral horn cells. The cells are large; they are probably really multipolar cells and some can be definitely seen to be so, although many seem to be rounded or bipolar cells. The nucleus is as a rule erratic in position.

Posterior Cells :

Certain small cells corresponding in position to Waldeyer's marginal, basal and central posterior cells occur. They are not constant anywhere but may be found at any level of the cord ~~after a~~ either as single cells or as a small group of at most three or four cells. They are small and very like the middle cells in appearance. I have not been able to separate them off definitely from the post-central middle cells on the one hand and from reticular cells on the other.

There are other cells which I have referred to as large isolated posterior cells. In size and appearance they are not unlike the anterior motor cells. They occur among the post-central middle cells, in

the hinder part of the formatio reticularis or further back in the outer posterior marginal zone, in the posterior basal or posterior central area, or, less commonly, on the inner posterior margin. In the upper cervical region they are very rare, merely an occasional single cell at long intervals; in the cervical enlargement they are found more often but always singly. In the dorsal region they again become rare and indeed appear quite wanting in some segments; in the lumbar cord they are much more abundant, at shorter intervals and sometimes two or even three may be seen in one section. They continue to be fairly common throughout the sacral region and are found even into the coccygeal segment.

In conclusion I have to express my thanks to Dr Alexander Bruce for suggesting this subject for a thesis; to Dr Theodore Shennan, Pathologist to the Royal Infirmary, in whose Laboratory the preparations of the sections was carried out; to Mr Henry Wade, Curator of the College of Surgeons' Museum for the use of the microphotographic apparatus and lastly, to the Carnegie Trust, since this thesis is part of work done under the terms of a grant from the trust for original research.